The Influence of Drip Fertigation on Water Use Efficiency in Tomato Crop Production

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Summary

The primary objective of this study was to determine the best irrigation and fertigation practice for tomato crop (*Lycopersicon esculentum* Mill.) in order to achieve highest yield with maximum water use efficiency (WUE). The field experiments were conducted during the period of May to September in 2002, 2003 and 2004. Five experimental treatments tested in this study included the following: the first three treatments (T1, T2, and T3) included a combination of drip irrigation and fertigation, treatment four (T4) included drip irrigation, but with conventional application of fertilizer, and the fifth treatment, (T5), included furrow irrigation practice with conventional application of fertilizer. The results of this study show that the drip fertigation treatments (T1, T2, and T3) gave significantly higher tomato yields in comparison with treatments T4 and T5, almost 24% and 39%. During three years of research treatments under drip fertigation showed almost 28% more water use efficiency in comparison with the treatment with conventional application of fertilizer and drip irrigation and 87% more than the treatment with furrow irrigation and conventional application of fertilizer. So, it is clear that the drip fertigation led to an increased yield, indicating enhanced water use efficiency.

Key words

tomato, irrigation, drip fertigation, yield, WUE

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Introduction

The geographic location and the related climatic conditions in the Republic of Macedonia are suitable for quality agricultural production; however the major limiting factors for higher yields and more profitable production are precipitation deficit, which is often aggravated by the uneven seasonal distribution, and the inefficient irrigation water use. Dry periods with different duration and intensity are common appearance, even in the humid calendar years. For example, over 20 consecutive calendar years on average there were 10 years with prolonged dry periods, nine years were close to the average, and one year was with appearance of floods. In addition to the prolonged draughts over the growing seasons the global warming threat is very likely to reinforce the ever increasing competing demands for water.

Over the past decade the vegetable growers in Macedonia have widely adopted the micro irrigation techniques. However they are still facing problems related to the optimal irrigation scheduling, water use efficiency as well as with the proper use of fertiliser when drip fertigation practice is used.

Combination of micro irrigation techniques with application of fertilizer through the irrigation system is a common practice in modern agriculture. Many authors in their drip fertigation research reports emphasize the advantages of this practice over the conventional methods of application of water and fertilisers. The advantages of drip fertigation are: the supply of nutrients can be more carefully regulated and monitored (Gardner et al., 1984; Burt et al., 1995), minimal losses of water and plant nutrients (Papadopoulos, 1985), decrease leaching and volatilization losses and minimize the chances for ground water pollution (Miller et al., 1981; Gardner et al., 1984; Papadopoulos, 1995), improved fertilizer use efficiency – FUE (Miller et al., 1981; Papadopoulos, 1995; Iljovski et al., 2003; Tanaskovik, 2005; Cukaliev et al., 2008), improved yield and water use efficiency (Al-Wabel et al., 2002; Papadopoulos, 1996; Halitligil et al., 2002; Cukaliev et al., 2007; Tanaskovik, 2005; Tanaskovic, 2007), improved yield quality parameters (Aleantar et al., 1999; Siviero et al., 1999) etc.

Therefore the primary objective of this study was to determine the best irrigation and fertigation practice for achieving tomato crop (*Lycopersicon esculentum* Mill.) yield potential. Simultaneously this study evaluated the impact of those practices on the water use efficiency (WUE) index. In order to achieve these objectives this study quantified the major benefits of drip fertigation practice relative to partially and fully conventional practices i.e. the ratios of yield increases and water use efficiency improvements.

Material and methods

The field experiment was conducted during the period May to September in the calendar years 2002, 2003 and 2004. The experiment was carried out at an experimental field near the Faculty of Agricultural Sciences and Food in Skopje (42º 00' N, 21º 27' E). The investigated crop was tomato (*Lycopersicon esculentum* Mill.), hybrid cultivar Optima. The soil type was coluvial (deluvial) soil (FAO Classification). The soil pH was 7.5. The soil 0-60 cm layers contained 2.40 mg/100 g available forms of N, 19 mg/100 g available P_2O_5 and 18 mg/100 g available K_2O. According to the literature data for the region, tomato planted in an open field in similar condition yields up to 80 t/ha (in good growing season with good agricultural practice). Tomato crop nutrient uptake for a 80 t/ha harvest totals approximately: N 260 kg/ha, P_2O_5 160 kg/ha and K_2O 320 kg/ha. The application of the fertilizer for the treatments was done in two portions (before planting and during the growing season), which is a common practice in Macedonia. For all treatments, the first portions of the fertilizers were applied before the planting. The reminder needed for achieving the targeted yield were applied through the fertigation system for the drip fertigation treatments, and by conventional fertilizer application for the control treatments (divided in two portions, flowering and fruit formation). All investigated treatments have received the same quantity of fertilizers, but with different methods of application (Table 1). This approach enabled us to quantify the impact of the different fertilizer application methods on the tomato crop water use efficiency.

A drip irrigation system was installed with integrated drippers, compensated, with discharge of 4 l/h. The fertigation equipment used for drip fertigation treatments was Dosatron 16, with a plastic barrel as reservoir for concentrated fertilizer. The discharge of the stock nutrient solution into the drip irrigation system averaged 1% of the total water discharge. The source of water was of high quality (municipal water supply system for city of Skopje). The irrigation of the tomato crop was scheduled according to the long-term average daily evapotranspiration calculated by FAO software CROPWAT for Windows 4.3 with crop coefficient (kc) and stage length adjusted for Skopje area. For the drip irrigation treatments (T1, T2, T3 and T4) the daily evapotranspiration and the corresponding irrigation rate were reduced by 20%, while the furrow irrigation treatment (T5) received the full irrigation rate determined by the aforementioned FAO model. The irrigation rates for all the treatments had been further reduced in order to compensate for the precipitation over the experimental periods. Therefore, all of the drip irrigation treatments have received the same amount of water, but with different frequency of application. This approach enabled us to determine the impact of various drip fertigation frequencies on the crop yield and WUE. The irrigation rates and irrigation frequency for tomato crop by treatment are shown in Table 2.

The irrigation scheme used in the experiment was designed according randomised block design for experimental purposes with five treatments in three replications. Experimental treatments were set up according to the daily evapotranspiration rate:

- Treatment 1 (T1). Fertigation according to daily evapotranspiration with application of water and fertilizer every two days
- Treatment 2 (T2). Fertigation according to daily evapotranspiration with application of water and fertilizer every four days
- Treatment 3 (T3). Fertigation according to daily evapotranspiration with application of water and fertilizer every six days
- Treatment 4 (T4). Drip irrigation according to daily evapotranspiration with application of water every four days and conventional fertilization (spreading of fertilizer on soil)
- Treatment 5 (T5). Furrow irrigation according to daily evapotranspiration with application of water every seven days and classic fertilization (spreading of fertilizer on soil)

Table 1. Type and amount of fertilizers and time and method of application

Treatments	Type of fertiliser	Total applied fertilisers in kg/ha per treatment	Time of application	Applied active matter in kg/ha per treatment		
				N	P_2O_5	K_2O
T1 T2 T3 T4 T5	NPK (15:15:15)	330	Before replanting	50.0	50.0	50.0
T1						
T2	Urea (46% N)	428	During the growing season with drip fertigation	197	—	—
T3	Soluble NPK (0:54:34)	179				
T4	Soluble NPK (4:4:40)	525	Spreading of fertilizer on soil in 2 phases:	—	93	60.0
T5			1. flower formation, 2. fruit formation	21	21	210
		1462	Total applied fertiliser in kg/ha per treatment	268	164	320

Table 2. Application rates and irrigation frequency for tomato crop by treatments

Period of vegetation in days		Application rate (mm)			
		Treatment 1	Treatments 2 and 4	Treatment 3	Treatment 5
May	20	3.2	6.4	9.6	14.0
Jun	30	6.4	12.8	19.2	28.0
July	31	9.6	19.2	28.8	42.0
August	31	8.0	16.0	24.0	35.0
September	10	4.8	9.6	14.4	21.0
Total	122	424.8	424.8	424.8	518.0
Irrigation frequency		every 2 days	every 4 days	every 6 days	every 7 days

The size of each plot (replication) was 7.2 m^2 (18 plants in 0.8 m spacing between the rows and 0.5 m plant spacing in the row). Each plot (replication) was designed with three rows of crop. There were six plants in each row. The rows from left and right hand side were border rows. The middle row was evaluated for experimental purposes. All six plants in the middle experimental row were used for sampling of water use efficiency (WUE). Above-ground biomass was collected (leaf, steam, fruits) and fresh and dry weight biomass (at 70°C for 48 hours, FAO/IAEA sample preparation techniques of biological material for isotope analysis) was measured. The results for WUE were determined as a ratio of the total dry matter biomass relative to the water used by crop (evapotranspiration). Collected data were subjected to statistical analysis of variance and means were compared using the least significant difference (LSD) at the 5% level of probability ($P<0.05$) test.

Results and discussions

The meteorological conditions during the research

The tomato crop needs a lot of heat during the whole growing period. If temperature is below 15°C the flowering stops and if temperature drops below 10°C the growth stops. The optimal temperature for growing tomato is 18-25°C during the day time and 15-16°C during the night. The average seasonal temperature for the experimental site (average in the growing period) during 2002, 2003 and 2004 was 21.0°C, 22.2°C and 20.5°C respectively (Table 3). During the most intensive fructification period (June-August) the average temperatures over the three experimental seasons were within the optimum values.

It is well known that tomato is most sensitive to water shortage (drought) during the flowering and fruit formation. The Skopje area in that period is characterized with highest temperatures and insolation, and consequently the evapotranspiration is highest as well. Usually rainfalls are minimal in that period. Data presented in the Table 3 shows that years 2002 and 2004 were characterized as very humid years with a lot of rainfall during the growing season (316.7 mm in 2002 and 250.3 mm in 2004) which is rather unusual for the Skopje region and the major vegetable production regions in Macedonia. Especially unusual were the rainfalls in the period July-September, 2002 and May-July, 2004. This created favourable conditions for plant diseases. Another problem was that experiment was set up according to the average evapotranspiration rate, so in a very wet period we had problems with excess water. In the case of fertigation, each skipped application of water resulted with less readily available nutrients for the crop. This created problems with the application of the total amount of nutrients with fertigation, especially in 2002, while in 2004 the more favourable rainfall distribution enabled us to apply the total planned quantity of nutrients. Year 2003 was close to the longer term averages. May and June in 2003 were characterized with slightly higher rainfall in comparison with the reminder of the growing period. In the period of most active yielding there was a severe shortage of water coupled with very high temperatures, and thus fertigation had a much higher effect on the measured parameters in 2003.

Tomato crop is characterized as a tolerant crop to low relative air humidity, even though optimal values are in the order of 55-65%. During the research period, the average relative humid-

Table 3. Monthly and growing season temperature, precipitation and relative humidity for Skopje in 2002, 2003 and 2004

Months	Temperature (°C)			Precipitation (mm)			Relative humidity (%)		
	2002	2003	2004	2002	2003	2004	2002	2003	2004
May	18.0	18.1	15.3	47.4	93.0	54.6	66	60	65
June	23.2	23.8	21.3	16.1	62.3	55.2	56	57	65
July	24.9	25.2	24.1	71.0	2.3	61.4	58	51	56
August	21.9	26.2	23.0	99.1	11.5	16.1	70	49	57
September	17.0	17.7	18.8	83.1	21.3	63.0	75	64	62
Total/Average	21.00	22.2	20.5	316.7	190.1	250.3	65	56	61

ity in all three years was close to optimal values. The measured values for the relative air humidity during the periods covered with the experiment are shown in Table 3.

Yield and yield components

The effects of fertigation and irrigation methods as well as the influence of drip fertigation frequency on tomato yield are shown in Table 4. There was no statistically significant yield difference between treatment T1 (118.03 t/ha) and treatment T2 (114.94 t/ha). Thus we can conclude that the drip fertigation frequency of two days, when compared to the four days frequency, does not increase the yield and the associated grower income. Therefore the decision about the fertigation frequency in a range of two to four days should be based on the other parameters such as the diameter of the pipes, the price of the pipes etc. Fertigation frequency of six days (T3) achieved yield that was significantly lower than the feririgation with frequencies of two and four days (T1 and T2). Hence, our results have confirmed that fertirrigation frequencies longer than four days result with significant tomato yield reduction due to the increased water deficit and water stress. Doorenbos et al. (1986) reported that prolonged water deficit limits growth and reduces yields of tomato crop. Phene et al. (1989) reported better tomato yields with high-frequency subsurface and surface drip irrigation (206 and 190 t/ha) in comparison with low frequency surface drip irrigation (179 t/ha).

The drip fertigation treatments (T1, T2, and T3) show a statistically significantly higher yield compared with drip irrigation treatment and spreading of fertilizer on the soil surface (T4). This can be explained by the fact that with drip fertigation the root zone is simultaneously supplied with water and readily available nutrients. Hagin et al. (2002) reported that in a fertigation system, the timing, amounts, concentrations and ratios of the nutrients are easily controlled. Due to this improved control, crop yields are higher than those produced by a conventional fertilizer application and irrigation. A number of other investigators report higher yields in different crops when fertilizers were injected through the drip system in comparison with conventional application of fertilizers (Locascio and Myers, 1974; Papadopoulos, 1996; Mosler, 1998; Castellanos et al., 1999; Pan et al., 1999; Al-Wabel et al., 2002; Iljovski et al., 2003; Tanaskovic, 2007; Cukaliev et al., 2008).

Yield difference between treatments with identical irrigation frequency of four days (T2 and T4) confirms that the yield is higher for about 22% with the growing season portion of the fertiliser applied trough the drip irrigation system (T2) when compared with the conventional spreading of similar fertiliser quantity (T4). This is a consequence of the fact that under drip irrigation only a small portion of soil volume around each plant is wetted, so crop root growth is essentially restricted to this wetted volume of soil and nutrients within that volume are subject to accelerated crop uptake. Haynes (1985) reported that if nutrients are applied outside the wetted soil volume they are generally not available for crop use. Therefore, our results clearly show that if drip irrigation is applied than fertilisers, or at least a portion of the fertilisers, should be applied by drip irrigation system. Burt et al. (1995) reported that the agricultural growers indicate the importance of drip fertigation under micro irrigation systems in producing higher yielding and better quality tomato crop.

The effects of irrigation techniques on the tomato yields are verified by the yield difference between treatment with drip irrigation and spreading of fertilizers on soil (T4) and treatment with furrow irrigation and application of similar quantity of fertilizers (T5). Namely, the T4 treatment shows a statistically significant yield difference when compared with treatment T5. This can be explained by the fact that with drip irrigation the plants are permanently provided with readily available water i.e. their crop water requirements are met in a timely manner. Dasberg and Or (1999) reported that increased yields using drip irrigation can be attributed to several factors: higher water use efficiency because of precise application directly to the root zone and lower losses due to reduced evaporation, runoff and deep percolation; reduced fluctuations in the soil water content resulting with avoidance of water stress and etc.

Also, the number of fruits per plant and the average weight of tomato fruit were investigated in this experiment. Therefore, an interesting observation is the effect of fertigation, irrigation method, and frequency of drip fertigation, on tomato yield components. The data for the yield components achieved in the experiment are shown in Table 5 and 6. According to those results, it is evident that more frequent application of water and fertilizer also create better environment for yield formation (Table 5).

The average weight of tomato fruit is not only biological feature of the variety; it is also a quality parameter, which can be used to determine the positive or negative effects of the production technology. The influence of different techniques of irrigation and fertigation and frequency of drip fertigation on the average weight of tomato fruit is presented in Table 6. From the data presented in Table 6 it is clear that there is not statistically significant difference between treatments T1 (217.7g) and T2 (219.7g). The treatment T3 (214.16g) shows statistically significant lower average weight of tomato fruit in comparison with T2 and T1, which is most likely due to the longer water and fertiliser application time increments. The drip fertigation treatments (T1, T2, and T3) show a statistically significant higher fruit weight when compared with treatment with drip irrigation and spreading of fertilizer (T4). Finally, the treatment with drip irrigation and spreading of fertilizers on soil (T4) shows a statistically significant higher fruit weight when compared with furrow irrigation and same application of the fertilizers (T5). A number of other investigators (Petrevska, 1999; Siviero et al., 1999; Aleantar et al., 1999; Tekinel et al., 2002; Tanaskovic, 2007) report better yield components in different crops especially when drip irrigation was used in comparison with other irrigation techniques (furrow or sprinkler), as well as when the drip fertigation was applied in comparison with conventional fertilizer application.

Water use efficiency (WUE)

The definition of water use efficiency (WUE) differs with the context in which it is applied i.e. it is defined differently by the various research disciplines such as agronomy, plant physiology, irrigation engineering and economics (Prihar et al., 2000). We opted for agronomic WUE indexes in our research i.e. the ratio of dry matter (fruit, leaf, steam) and water used by the crop (ET).

The water used by tomato crop (ET) was determined by the water balance method (Iljovski and Cukaliev, 2002; Evett, 2007) at the 0-100 cm soil layer. The main parameters for estimation of water balance were effective precipitation (P), irrigation (I), initial or active water in soil at the beginning of vegetation (Wi) and active water in soil at the end of vegetation (We). Evapotranspiration (ET) was determined with the equation ET= (P+I+Wi)-We. From the results of our research (Table 7), it can be concluded that there are negligible evapotranspiration (ETP) differences among the drip irrigation treatments. On the other hand, the control treatment under furrow irrigation and spreading of fertilizer (T5) showed relatively higher ETP (in the range of 30 to 34%) when compared with the drip irrigation treatments.

The impact of conventional application of water and fertilizer, drip irrigation with spreading of fertilizer, and drip fertigation with different frequency of water application, on the water use efficiency (WUE) of tomato is presented in Table 7. From the results shown in Table 7, it can be concluded that the total dry matter yield (D.M.yield t/ha) under the drip fertigation method is statistically significantly higher than the control treatments T4 and T5. The total dry matter yield shows the same pattern as a fresh fruit yield, which once again indicates yield increases due to simultaneous application of water and nutrients through the drip irrigation system. Sagheb et al. (2002) reported that with the same quantity of fertilizer but different methods of application, drip fertigation shows about 2.7 times more total dry matter in comparison with treatment with furrow irrigation and spreading of fertilizers on soil.

The obtained results for water use efficiency (WUE) were 2.34 kg/m^3, 2.15 kg/m^3, 1.94 kg/m^3, 1.84 kg/m^3, and 1.25 kg/m^3 respectively for the treatments T1-T5 that were included in this experiment. There was a statistically significant difference among all five treatments. The differences between the treatments with drip fertigation are result of irrigation frequencies. Phene et al. (1989) reported higher water use efficiency in the treatments with high-frequency subsurface and surface drip irrigation (several irrigations each day) in comparison with low frequency surface drip irrigation (one irrigation at 2-3 days). If the results for WUE in our research are presented as comparative values, then water use efficiency in the treatments T1 and T2 is for 87 and 72% higher in comparison with T5, while in comparison with T4 WUE is about 28 and 17% higher. The treatment T3 obtained almost 6% higher water use efficiency in

Table 4. The influence of irrigation and fertigation treatments on tomato yield

Treatments	Yield (t/ha)	Comparison with furrow irrigation (%)	Comparison with drip irrigation and spreading of fertiliser (%)
T1	118.03^a	138.91	124.33
T2	114.94^a	135.27	121.10
T3	106.55^b	125.39	112.24
T4	94.93^c	111.72	100.00
T5	84.97^d	100.00	

*Values in rows followed by the same letter are not significantly different at the 0.05 probability level

Table 5. The influence of irrigation and fertigation treatments on the number of fruits per plant

Treatments	Number of fruits per plant	Comparison with furrow irrigation (%)	Comparison with drip irrigation and spreading of fertiliser (%)
T1	21.32^a	120.45	117.79
T2	20.61^b	116.44	113.87
T3	19.61^c	110.79	108.34
T4	18.10^d	102.30	100.00
T5	17.70^e	100.00	

Table 6. The influence of irrigation and fertigation treatments on average weight of tomato fruit

Treatments	Average weight of tomato fruit (g)	Comparison with furrow irrigation (%)	Comparison with drip irrigation and spreading of fertiliser (%)
T1	218,70^a	116.37	105.70
T2	219,77^a	116.94	106.22
T3	214,16^b	113.95	103.50
T4	206.91^c	110.09	100.00
T5	187,93^d	100.00	

Table 7. Water use efficiency by tomato crop

Treatments	D.M. yield (kg/ha)	ETP (m^3/ha)	WUE (kg/m^3)	Comparison with T5 (%)	Comparison with T4 (%)
T1	9990^a	4270	2.34^a	187.2	127.2
T2	9500^a	4425	2.15^b	172.0	116.9
T3	8710^b	4501	1.94^c	155.2	105.4
T4	8160^c	4425	1.84^d	147.2	100.0
T5	7300^d	5825	1.25^f	100.0	

*Values in rows followed by the same letter are not significantly different at the 0.05 probability level; D.M. yield kg/ha= dry matter yield per unit area; ETP m^3/ha = potential evapotranspiration; WUE=water use efficiency comparison with T4 and about 52, 2% in comparison with T5, as a result of improved nutrient availability when application of fertilizer is done through the drip irrigation system. Oertli et al., (1989) reported that fruit biomass and WUE respond strongly to improved nutrition. A number of other investigators (Phene et al., 1989; Papadopoulos, 1996; Halitligil et al., 2002; Sagheb et al., 2002; Iljovski et al., 2003; Tanaskovik, 2005) reported higher water use efficiency as result of drip irrigation and fertilizer application trough the system in comparison with furrow irrigation and spreading of fertilizers on soil. Cukaliev et al. (2003) reported that when fertilizers are simply broadcast over the entire soil area may become limiting factor for plant growth. Also, this occurrence could be a consequence of fertilizer leaching from the root zone, as well as because of volatilization losses (Miller et al., 1981). Various research reports indicate that drip fertigation create conditions for higher fertilizer use efficiency, which contributes to decreased leaching of fertilizers and minimizes the chances for soil or ground water pollution (Gardner et al., 1984; Papadopoulos, 1995; Cukaliev et al., 2008). Finally, as a result of irrigation technique and irrigation frequency, the treatment T4 obtained 47% higher WUE in comparison with T5. This can attributed to the wasteful water application and lower yield obtained by the conventional irrigation. Prihar et al. (2000) reports that WUE can be enhanced by (1) increasing seasonal ET, (2) increasing the T component of ET, (3) regulating T in sensitive crop growth periods, and (4) ensuring optimal crop nutrition. These principles have been mainstreamed in the advanced field practices. The most important principles that have been translated into the recent field practice improvements include matching water needs of crops and cropping systems with available water supplies, fertilization, tillage and mulching.

Conlusions

The drip fertigation method yielded 39% higher tomato yield when compared to furrow irrigation combined with conventional fertilizer application (T5), and 24% higher yield than drip irrigation combined with conventional fertilizer application (T4). The tomato yields under drip fertigation treatments (T1, T2 and T3) were statistically significantly higher in comparison with the semi-conventional and conventional treatments (T4 and T5). The effect of different methods of fertilizer application was quantified by the significant differences in tomato fruit yield between treatment T2 and treatment T4. Yield difference between these two treatments (similar amount of water was applied with similar frequency - every four days) proved that when fertilizer is applied through the drip irrigation system (T2) the yield was higher by about 21% when compared with the conventional spreading of fertilizer on the soil surface (T4).

This study also resulted with statistically significant differences between yield components in drip fertigation treatments (T1, T2, T3) in comparison with furrow irrigation and spreading of fertilizers on soil (T5) and drip irrigation and spreading of fertilizers on soil (T4). Overall, fertigated treatments achieve better results. Also, the results of yield components in drip irrigation treatment (T4) are better in comparison with furrow irrigation (T5). The differences in yield components between treatments T4 and T5 are statistically significant.

The superior effect on tomato yield of the combined application of water and fertilizer via the drip irrigation system was additionally confirmed by the dry matter yield measurements that followed the same pattern as the fresh fruit yields.

The results from this study show that water use efficiency (WUE) in tomato crop production respond strongly to proper fertigation and irrigation regime. If drip ferttigation is used in tomato crop production (T1, T2 and T3) than water use efficiency is from 52 to 87% higher in comparison with treatment with furrow irrigation and spreading of fertilizers on soil (T5), and from six to 27% higher in comparison with treatment with drip irrigation and spreading of fertilizers on soil (T4). If drip irrigation is used in tomato crop production (T4) than water use efficiency is 47% higher in comparison with treatment with furrow irrigation (T5).

Generally, the benefits of combining drip irrigation with fertigation range from tomato yield and yield component increases to improved water use efficiency. In addition, drip fertigation is an effective method to protect the environment, because the applied nutrients are not leached beyond the root zone during irrigation as well as because of the reduced volatilization losses. Finally, from our research we can conclude that the optimal frequency for irrigation and fertigation of tomato crop in similar conditions is two to four days.

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